CHAPTER 2

STORMWATER QUANTITY

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INTRODUCTION

Urban development generally increases both the rate and total volume of stormwater runoff. When an area is urbanized, the amount of impervious surfaces is increased, which changes its response to precipitation. The increase in impervious surfaces decreases the amount of precipitation that can infiltrate and decreases the runoff travel time through the watershed.

CURRENT RESEARCH AND CONCLUSIONS

Schueler (1987), describes the following hydrological changes resulting from urbanization:

- Increase peak discharges about two to five times higher than pre-development levels (Leopold, 1968; Anderson, 1970).

- Increase in volume of storm runoff produced by each storm, in comparison to pre-development conditions. A moderately developed watershed may produce 50% more runoff volume than a forested watershed during the same storm.

- Decreased time needed for runoff to reach the stream (time of concentration) by as much as 50% (Leopold, 1968), particularly if extensive drainage improvements are made.

- Increased frequency and severity of flooding. A short, intense summer thunderstorm that had only slightly raised water levels in the past now turns the stream into a torrent. In a natural state, a stream experiences bankfull discharges (i.e., runoff entirely fills the stream channel) only about once every two years. In moderately developed watersheds, bankfull discharges may occur as often as three or four times a year.

- Reduced streamflow during prolonged periods of dry weather due to the reduced levels of infiltration in the watershed. In smaller, headwater streams, the reduction may be enough to cause a perennial stream to become seasonally dry.

- Greater runoff velocity during storms, due to the combined effect of higher peak discharges, rapid time of concentration, and smoother hydraulic surfaces that occur as a result of development.

These changes to the watershed hydrology require a consideration of three different aspects of urban hydrology:

- The potential flooding of downstream properties, and/or exceeding of the capacity of downstream drainage structures, due to the increase in peak runoff;

- The potential for streambank erosion, due to the increase in peak runoff;
- And the quantity of runoff which should receive stormwater treatment, for the removal of urban pollutants.

FLOODING

Historically the main concern of urban drainage design has been flood control. Drainage systems were designed to convey the runoff from a "design storm" off-site. This was done so that flooding of downstream properties was not a problem, and the capacity of downstream drainage structures was not exceeded, but rapid enough to prevent impacts to the property under consideration. Design storms have been based upon a 10, 25, 50, or even 100-year return frequency, i.e., storms that are uncommon.

While still of major concern, flooding is not the only concern. From a water quality perspective these large storms are not as great a concern. Most of the runoff volume, and therefore most of the mass pollutant discharges, are generated by smaller storms simply because there are many more of them.

The design storm presently used for flood control varies widely with 10, 25 and 50 year storms being very common. As discussed later. the 2-year storm event, although not usually causing flooding problems, needs to be considered in design of detention facilities to prevent streambank erosion. Another concept that must be considered is the potential cumulative impact of a series of detention facilities in an individual watershed. A detention facility low in a watershed may detain stormwater long enough to coincide with the peak discharge for the watershed at that location thus increasing the peak flow. In addition the cumulative impact of development and stormwater detention facilities on a watershed is of concern

STREAMBANK EROSION

A typical stream channel is naturally sized to flow bank full during a one or two year storm event. Urbanization of a watershed will increase the runoff from this storm event. Schueler (1987) describe the following in reference to streambank erosion effects associated with urbanization:

- The primary adjustment to the increased storm flows is through channel widening. Numerous surveys (Robinson, 1976; Fox, 1974; Hammer, 1972) and anecdotal evidence (Ragan and Dietemann, 1976) have shown that most streams widen two to four times their original size if post-development runoff is not effectively controlled. The resulting streambank erosion is severe because most floodplain soils are unconsolidated and highly erodible.
- The elevation of the stream's floodplain must increase to accommodate the higher post-

development peak discharge rate. Property and structures which had not previously been subject to flooding now may be at risk.

- Streambanks are gradually undercut and slump into the channel. Trees that had protected the banks are gradually exposed at the roots, and are more likely to be windthrown, triggering a second phase of bank erosion.

- The prodigious quantities of the sediment eroded from streambanks and upland areas are seldom completely exported from the watershed. Much of it remains as temporary channel storage as sandbars and other sediment deposits. Gradually, the extra sediment moves through the stream network as bedload. However, for many years the channel substrate is covered by shifting deposits of mud and sand.

DESIGN FOR STORMWATER TREATMENT

Research by Pitt (1993) has shown that small storms are the important ones for water quality investigations, he reached the following conclusions:

- Storms less than 0.5 inches are important for water quality standard violations, especially for bacteria

- Storms from 0.5 to 1.5 inches are responsible for most pollutant mass discharges

- Larger storms are much less common and are important in the design of conveyance systems. In addition, the runoff from these larger storms may be dominated by runoff from pervious areas.

Further:

- During the 1983 NURP monitored rain year for Milwaukee, 66 percent of all rains were less than 0.5 inches in depth

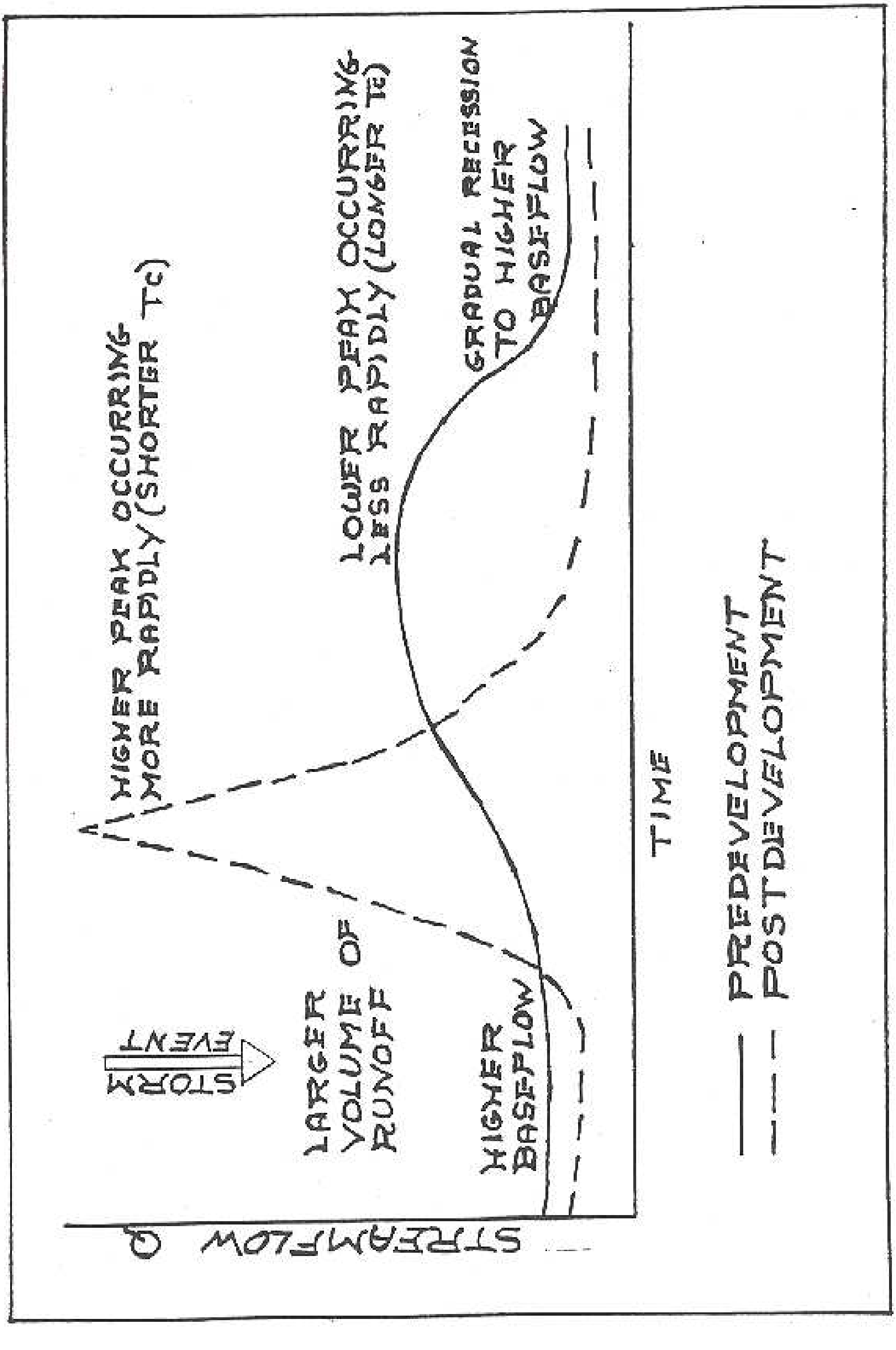
- For medium density residential areas, 50 percent of runoff was associated with rains less than 0.75 inches.

- A 100 year, 24 hour rain of 5.6 inches for Milwaukee could produce about 15 percent of the typical annual runoff volume, but only contributes about 0.15 percent of the average annual runoff volume, when amortized over 100 years.

- Typical 25 year design storms (4.4 inches in Milwaukee) produce about 12.5 percent of typical annual runoff volume but only about 0.5 percent of the average runoff volume.

An analysis, by the New Hampshire Department of Environmental Services, of precipitation records for the period 1978 to 1994, of the Concord, NH Weather Service Observatory showed that about one half the events were less than about 0.3 inches in rainfall, and about one half the rainfall volume were produced by events of one inch or less. A two year, 24 hour storm in Concord produces approximately 2.85 inches of rainfall. This magnitude storm is larger than approximately 98 percent of the events. Storms of this magnitude or less produce approximately 91 percent of the rainfall volume.

Figure 2.1: Changes in Watershed Hydrology as a Result of Urbanization



CONCLUSIONS AND SUMMARY

The two year-24 hour storm represents over 91 percent of the total rainfall and 98 percent of the measurable rainfall events. In addition control of the two year-24 hour storm is critical for control of streambank erosion. This would make the selection of the two year-24 hour storm as the storm to control for water quality purposes, a good selection for regulatory purposes.

Another consideration in design storm selection is the availability of design information. The SCS curve number method includes two year-24 hour information in its design manual and most rainfall frequency charts used in the Rational Method include two year storm events. Information on more frequent storms is not as readily available.

For flooding purposes, the 10-year storm event has proven satisfactory over the life of the New Hampshire Department of Environmental Service's Site Specific Program. This program permits large developments, regulating soil erosion control and stormwater management. If a larger but less frequent design storm is required by other jurisdictions, a multiple outlet design can readily accommodate all requirements.

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